## Title

Environmental Regularities Shape Semantic Organization throughout Development



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# Environmental Regularities Shape Semantic Organization throughout Development


## Abstract

Our knowledge of the world is an organized lexico-semantic network in which concepts can be linked by relations, such as "taxonomic" relations between members of the same stable category (e.g., *cat* and *sheep*), or association between entities that occur together or in the same context (e.g., *sock* and *foot*). Prior research has focused on the emergence of knowledge about taxonomic relations, whereas association has received little attention. The goal of the present research was to investigate how semantic organization development is shaped by both taxonomic relatedness and associations based on co-occurrence between labels for concepts in language. Using a Cued Recall paradigm, we found a substantial influence of co-occurrence in both 4-5-year-olds and adults, whereas taxonomic relatedness only influenced adults. These results demonstrate a critical and persistent influence of co-occurrence associations on semantic organization. We discuss these findings in relation to theories of semantic development.



**Keywords:** semantic development; semantic organization; categories


## Introduction

Our knowledge about the world is fundamental to many of the cognitive feats we accomplish on an everyday basis, including applying what we know to new situations, retrieving knowledge from memory, and incorporating new information into existing knowledge (Bower, Clark, Lesgold, & Winzenz, 1969; Heit, 2000; Tse, Langston, Kakeyama et al., 2007). These feats are possible due to the organization of our knowledge into an interconnected lexico-semantic network of related concepts (Cree & Armstrong, 2012; McClelland & Rogers, 2003). For example, our knowledge of dogs is often connected to our knowledge of other similar animals (e.g., cats), as well as to our knowledge about the contexts in which dogs appear, such as with leashes and doghouses.

Although the fact that our concepts are organized is hardly controversial (e.g., McClelland & Rogers, 2003), the processes that drive the development of semantic organization are a topic of considerable debate. To date, this debate has focused on how connections between concepts from the same stable, "taxonomic" category (e.g., *animals*, *foods*) are formed, in spite of the fact that they may be difficult to observe: Members of the same (especially superordinate) taxonomic category do not necessarily look similar, or occur together. Some have proposed that semantic development begins with easy to observe relations that are then used to bootstrap taxonomic knowledge (Lucariello, Kyratzis, & Nelson, 1992). Alternately, others have proposed that we are endowed with early-emerging biases towards learning taxonomic relations (e.g., Gelman & Markman, 1986).

The goal of this research is to investigate another possibility: That easy to observe relations – specifically, co-occurrence – play a fundamental role in shaping knowledge organization from early in development through adulthood. In this paper, we first review traditional theoretical accounts that have focused on taxonomic relations, then highlight key findings suggestive of a role for co-occurrence that these accounts fail to capture, and an alternate perspective that we test in the present experiment.

### Traditional Accounts of Semantic Development

Most extant accounts of the development of semantic organization have focused on how semantic knowledge becomes organized according to membership in taxonomic categories, such as *foods*. According to some accounts, referred to here as *restructuring* accounts, taxonomic relations are the endpoint of development. Critical to these accounts is the idea that the order in which relations between concepts are acquired is dictated by how observable they are. For example, it is easy to observe that cups have the same shape, or reliably co-occur with juice or milk, whereas membership in the same superordinate taxonomic category is more difficult (if not impossible) to observe. Restructuring accounts propose that early organization is shaped by information readily available in the environment, and that taxonomic knowledge comes to replace this (more rudimentary) organization.

An early restructuring account was proposed by Inhelder and Piaget (1964), in which the transition to taxonomic organization is driven by experiences that highlight the inadequacy of earlier modes of organization (although the mechanisms by which this transition occurs are not clear). Another, more specified restructuring account is Nelson and Lucariello's (1992) slot-filler account, which highlights environmental input in which some members of the same taxonomic category play the same role in the same context, such as some members of the taxonomic category of *foods* (e.g., eggs and bacon) reliably *being eaten* in a *breakfast* context. According to this account, young children are sensitive to these regularities, such that semantic knowledge is first organized into contextually-constrained taxonomic groups, which are gradually integrated together as children recognize when entities play the same role in different contexts (e.g., foods *being eaten* in different meal contexts).

According to another set of accounts, referred to here as *taxonomic bias* accounts, taxonomic relations predominate semantic organization from early in development due to early-emerging (possibly innate) biases towards learning which entities are members of the same taxonomic category. These biases include beliefs that entities in the world belong to taxonomic categories, and that labels are indicative of category membership (e.g., Gelman & Coley, 1990). A role for other types of environmental input, such as the regularity with which entities co-occur, is not specified.

A final type of account reviewed here, which we refer to as *featural learning*, posits that the development of semantic organization is driven by detecting clusters of features whose appearance in entities is reliably correlated, and which are often associated with taxonomic category membership (Rosch, 1975). For example, membership in the category of *birds* is associated with possessing *wings, feathers,* and a *beak*. Featural learning accounts propose that sensitivity to these correlations yields taxonomic organization (e.g., McClelland & Rogers, 2003). In contrast with taxonomic bias accounts, featural learning accounts argue in favor of the gradual emergence of taxonomic organization over the course of development. However, featural learning accounts do not consider spatial or temporal co-occurrence of items in the world (or language) as contributors to semantic organization.

## Environmental Regularities Overlooked by Traditional Theoretical Accounts

Of the influential accounts reviewed in the previous section, only some restructuring accounts posit any role in semantic development for environmental regularities with which entities and their labels co-occur. Even in these accounts, these regularities are ultimately overwritten. However, several findings highlight a potential importance of co-occurrence regularities *throughout* development.

First, statistical learning studies suggest that sensitivity to the regularity with which different entities co-occur is apparent from very early in development (Bulf, Johnson, & Valenza, 2011). Moreover, numerous findings attest to the influence on children's reasoning of semantic relations that may be derived from co-occurrence, such as *schematic* relations between entities that occur in the same context (e.g., *cow* and *barn*) and *thematic* relations between entities that play complementary roles (e.g., *nail* and *hammer*) (Blaye, Bernard-Peyron, Paour, & Bonthoux, 2006; Fenson, Vella, & Kennedy, 1989; Lucariello et al., 1992; Walsh, Richardson, & Faulkner, 1993). Additionally, a handful of studies conducted by Fisher, Godwin and Matlen (Fisher, Matlen, & Godwin, 2011; Matlen, Fisher, & Godwin, 2015) point more directly towards an influence of co-occurrence on children's semantic reasoning. In these studies, participants were asked to infer whether a property (e.g., "has blicket inside") attributed to a target (e.g., glove) was shared by either a strongly taxonomically related item (e.g., mitten) or a more weakly taxonomically related item (e.g., sweater). These studies revealed that four year old children only reliably chose the strongly taxonomically related item when its label co-occurred with the target either in corpora of children's speech input (e.g., bunny-rabbit, Fisher et al., 2011) or an empirically manipulated speech stream (Matlen et al., 2015). These findings suggest that accounts of semantic development that do not posit any role for co-occurrence are at best incomplete.

Second, a handful of findings suggest that semantic relations that may be derived from co-occurrence continue to shape semantic organization into adulthood. For example, Lin and Murphy (2001) found that relations between entities that adult raters judged as associated in scenes or events (which likely co-occur) had a pervasive influence on adults' categorization and reasoning that was frequently greater than the influence of taxonomic relations. This evidence is inconsistent with restructuring accounts, in which an early influence of co-occurrence is eventually overwritten.

Finally, the potential contributions of co-occurrence regularities are highlighted by a mechanistic account and corroborating behavioral evidence presented by Sloutsky, Yim, Yao, and Dennis (2017). According to this account, exposure to co-occurrence regularities in language fosters both the learning of associations between concepts whose labels directly co-occur in sentences (e.g., *fork* and *spaghetti*), and between taxonomically related concepts whose labels share patterns of co-occurrence (e.g., *spaghetti* and *pie*). However, whereas co-occurrence in a sentence can be directly gleaned from input and therefore rapidly learned, shared patterns of co-occurrence that often link members of the same taxonomic category are learned more slowly because they can only be derived from multiple instances of direct co-occurrence. This account predicts both that (1) direct co-occurrence should contribute to semantic organization throughout development, and (2) the contributions of direct co-occurrence to semantic organization should be evident earlier in development than the contributions of taxonomic relatedness. Initial evidence for this account comes from a series of experiments presented in Sloutsky et al. (2017) in which children and adults were asked to infer the category membership of a novel word (e.g., whether it was an animal or a machine) that was presented within a list of familiar words. Both children and adults readily inferred the category membership of the novel word when it appeared in a list of words that are associated (and therefore likely to co-occur) with the same category. For example, participants inferred that the novel word referred to an animal when it appeared in a list of words including "furry" and "zoo". However, only adults inferred this meaning when the novel word appeared in a list of words referring to *members* of the category, such as "lion" and "bunny".

Together, these prior findings suggest that co-occurrence regularities may shape semantic development. However, in addition to being overlooked in traditional theoretical accounts of the development of semantic organization, this possibility has received only limited empirical investigation to date, and the way in which it has been investigated has not been designed to assess relational knowledge for items that *actually* co-occur in the environment. Critically, this research has instead investigated knowledge for relations between items either judged by researchers or participants as co-occurring according to researcher-specified criteria, or produced in free association tasks. Neither ratings nor free associations are inputs from the environment from which semantic relations can be learned: They are *outcomes* of relations already learned and present in semantic knowledge (Hofmann, Biemann, Westbury et al., 2018). A more direct investigation of the role of co-occurrence in shaping semantic development could be accomplished by assessing the contributions of co-occurrence regularities present in actual environmental input.

## Current Study

The overall purpose of the current study was to investigate the contributions of co-occurrence regularities and taxonomic relatedness to the organization of lexico-semantic knowledge from early childhood to adulthood. This investigation was designed to arbitrate between competing theoretical accounts of the development of knowledge organization. Specifically, restructuring accounts predict that co-occurrence should contribute to knowledge organization in childhood, but be replaced by taxonomic relations in adulthood. Both taxonomic bias and featural learning accounts are agnostic about the contributions of co-occurrence, but whereas the former predict that taxonomic relations should contribute from childhood through to adulthood, the latter predict that the contributions of taxonomic relations should substantially increase with age.

A different developmental pattern is predicted by recent proposals that highlight a key role throughout development for co-occurrence in which it both directly fosters relations between concepts, and indirectly fosters relations between concepts that share patterns of co-occurrence and are often taxonomically related (e.g., Sloutsky et al., 2017). Specifically, such proposals predict that the contributions of co-occurrence should be evident in both children and adults, whereas contributions of taxonomic relatedness should be evident only later in development.

We accomplished this investigation by measuring the degree to which familiar concepts were related in young children (4-year-olds) and adults' semantic knowledge when either the concepts' labels reliably co-occur in linguistic input, or when they are members of the same taxonomic category. To target actual experienced co-occurrence, we identified pairs of words familiar to young children that co-occurred more reliably with each other than with other words in corpora of child-directed speech.

To measure the contributions of co-occurrence and taxonomic relations to children and adults' lexico-semantic knowledge, we used a Cued Recall paradigm to measure the effects of co-occurrence and taxonomic relatedness on memory retrieval. We selected this paradigm for two reasons. First, the sensitivity of this task to semantic relatedness is attested by numerous findings that semantic relatedness influences the accuracy with which people (including children) recall word pairs and lists (Bjorklund & Jacobs, 1985; Blewitt & Toppino, 1991). Second, this task facilitates a comparison between children and adults because it measures contributions to lexico-semantic knowledge without requiring participants to reason about relations, which adults may more easily.

Table 1: Pairs of words used in the Co-Occur, Taxonomic, and Unrelated conditions

| Co-Occur | | Taxonomic | | Unrelated | |
|---|---|---|---|---|---|
| bottle | baby | ball | puzzle | crayon | frog |
| foot | shoe | pig | bear | towel | bread |
| brush | hair | horse | bunny | blocks | cereal |
| cup | juice | carrot | banana | balloon | tree |
| cheese | mouse | fork | bowl | sheep | pancake |
| car | street | popcorn | fries | pizza | lion |
| soup | spoon | airplane | boat | fish | bed |
| milk | cow | sock | pajamas | duck | swing |

# Method

## Participants

The sample included 30 4-5 year old children ($M_{age}$=4.50 years, $SD$=1.62 years), and 29 Adults ($M_{age}$=20.16 years, $SD$=3.66 years). The child age group was selected because the 4-5 year period is one during which the nature of relations that organize lexico-semantic knowledge has been the subject of active debate (Lucariello et al., 1992; Nguyen & Murphy, 2003; Waxman & Namy, 1997). Children were recruited from families, daycares, and preschools in a metropolitan area in a Midwestern US city. Adults were undergraduates from a public university in the same city and participated in exchange for partial course credit.

## Stimuli and Design

The primary stimuli used in this experiment were word pairs that belonged to one of three Semantic Relatedness conditions: Co-Occur (pairs that reliably co-occurred with each other more often than with other words in child speech input), Taxonomic (words close in meaning from the same taxonomic category) or Unrelated. (words that neither reliably co-occur nor are similar in meaning).

**Co-Occurrence Criteria**. The first step taken to select pairs in each condition was to identify a set of words for which lexical norms collected using the MacArthur-Bates Communicative Development Inventory (MB-CDI) were available from WordBank (an open database of children's vocabulary development, Frank, Braginsky, Yurovsky, & Marchman, 2016), and measure their rates of co-occurrence in 25 child speech input corpora from the CHILDES database (MacWhinney, 2000). To reduce the computational expense of measuring word co-occurrence rates, some classes of words that would *a priori* not be used as stimuli were removed, such as sounds (e.g., "moo"), leaving a list of 538 words. Additionally, to ensure that co-occurrences were measured from speech *input*, CHILDES corpora were pre-processed to remove speech produced by children. Co-occurrences between these words were then calculated by taking all possible pairs of words in this set, and calculating how frequently they co-occurred with each other within a 7-word window across 25 CHILDES corpora. Finally, to account for the fact that more frequent words co-occur with other words simply by chance, t-scores (Evert, 2008) were calculated for each word pair using the formula below based on their measured co-occurrence frequencies (O), adjusted for the frequency of co-occurrence expected by chance based on their respective frequencies across the corpora and the size of the corpora (E):

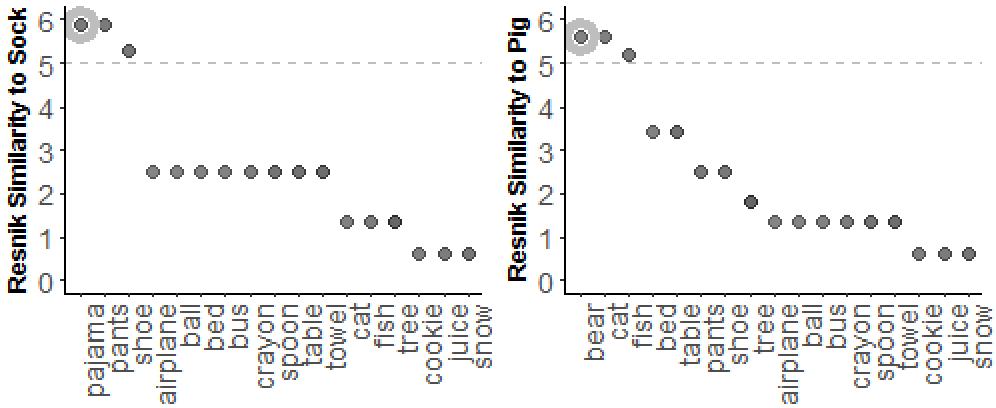


Figure 1: Graphs depicting Resnik similarity between one item from a Taxonomic pair and: (1) The other item from the pair (highlighted), (2) Other items from the same taxonomic category, and (3) Items from other categories.

$$t.score = \frac{O - E}{\sqrt{O}}$$

Word pairs for use in the Co-Occur condition were then selected as pairs of nouns with t-scores > 2.5 (following Baayen, Davidson, & Bates, 2008) in which, according to lexical norms accessed from WordBank, both words were produced by >80% of 36-month-old children (one year younger than children in our sample).

**Taxonomic Criteria**. Taxonomic relatedness was determined based on both the membership of concepts in the same taxonomic category (e.g., clothing, foods, animals) and similarity in *meaning* between their labels. Similarity in meaning was measured as similarity between the definitions of candidate words from WordNet (a database of word definitions composed by lexicographers). This measure captures the essence of taxonomic relatedness – i.e., close similarity in meaning – without relying on participant judgments that may be influenced by non-taxonomic relations (Wisniewski & Bassok, 1999). In WordNet, nouns are first grouped into sets of synonyms, which are in turn linked into a hierarchy according to "IS A" and part-whole relations. Similarity in meaning between word pairs was measured using Resnik similarity, i.e., the information content (specificity) of the word lowest in the WordNet hierarchy within which the pair of words is subsumed. For example, *dog* and *cat* are subsumed within *carnivore*, whereas *dog* and *kangaroo* are subsumed within mammal; because the information content of carnivore is greater than the information content of mammal, Resnik similarity is higher between dog and cat versus dog and kangaroo.

Candidate Taxonomic pairs nouns with Resnik similarities of > 5 and t-scores < 1.5 in which both were produced by at least 80% of 36-month-old children according to WordBank norms. The rationale of the Resnik similarity criterion of > 5 is illustrated in Fig. 1, which shows that this value distinguished between same- vs. different-category items.

**Unrelated Criteria**. Candidate Unrelated word pairs were noun pairs that met the WordBank production norm criterion with t-scores and Resnik similarities of < 1.5.

**Composition of Full Set**. From the sets of candidate pairs, eight pairs were selected for each of the Relation conditions (Co-Occur, Taxonomic, and Unrelated) such that: 1) The mean percentage of 36-month-olds who produced the words in the pairs according to Wordbank norms was equated across conditions, and 2) No words appeared in more than one condition (Table 1). An additional 4 nouns that met the WordBank production norm criterion were selected to construct pairs used for demonstration and practice (see Procedure below). All words were recorded by both a male and a female speaker using an engaging, child-friendly intonation.

The eight pairs in each Relation condition were divided into two Stimulus Sets, each with four pairs in each condition, because pilot testing indicated that 12 pairs was the maximum number that could be presented to children without producing floor effects. Within each Stimulus Set, each word in a pair was randomly assigned to be either the Cue or Target. In the experiment, Cue words were presented using the male speaker's voice, and Targets using the female's voice. Additionally, the 12 word pairs were pseudorandomized into three blocks, such that each block contained 1-2 pairs from each condition. The order of these blocks was counterbalanced across participants.

**Procedure.** Adult participants were tested in a quiet space in the lab, and children were tested either in a quiet space in the lab, or at their preschool or daycare. The procedure was identical for adults and children (including the auditory presentation of the same recorded Cue-Target pairs), with the exceptions that: 1) Instructions were conveyed by an experimenter for children, and as text on a computer screen for adults, and 2) Children made verbal responses recorded by the experimenter, whereas adults typed responses.

To start, participants were informed that they were going to play a game with two sock puppets depicted on the computer, Izzy and Ozzy, in which Izzy and Ozzy would say pairs of words. The two demonstration/practice unrelated Cue-Target spoken word pairs were then played, while animations depicted one puppet "saying" the Cue word, and the other saying the Target word. Participants

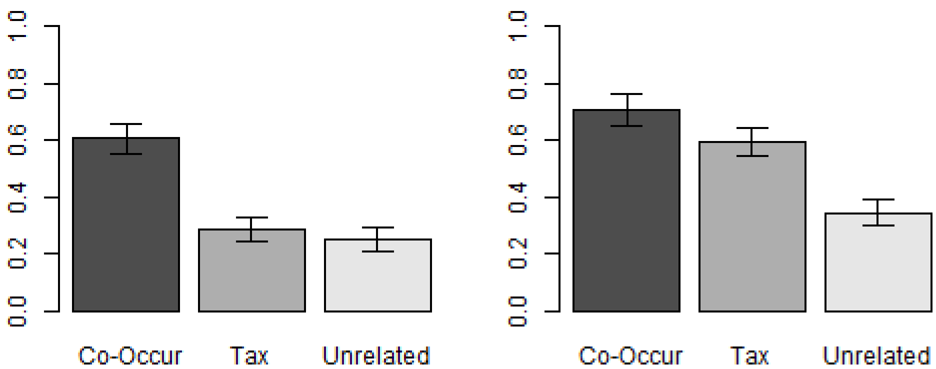


Figure 2: Accuracy in children (left) and adults (right) in the Relation Conditions. Error bars represent standard errors.

then completed two practice rounds with the same Cue-Target pairs consisting of a Study Phase, in which participants were instructed to remember the words that went together in pairs, and a Test phase, in which only the Cue in each pair was presented and participants were prompted to either say or type the Target that had been spoken by Ozzy. Participants received corrective feedback after each practice trial, and completed up to three practice rounds until they either responded with the correct Target for both Cues within around, or the experiment was terminated.

Participants then proceeded to complete the three blocks of Cue-Target pairs in the Stimulus Set to which they had been randomly assigned. Each block followed the same Study and Test phase format as the practice rounds, with the exception that participants did not receive feedback.

## Results

The primary outcome measure of interest for this study was the accuracy with which participants recalled Target words paired with Cues in each of the three Relation conditions: Co-Occurrence, Taxonomic, and Unrelated[1]. Responses were scored as accurate when participants made responses identical to the Target, morphological variants of the Target (e.g., “spoons” instead of “spoon”), or close synonyms to the Target (e.g., “road” instead of “street”).

All analyses were conducted in the R environment. Mixed effects models were generated using the lme4 (Bates, Maechler, Bolker, & Walker, 2015) package, and corresponding $\chi^2$ or F-statistics for main effects and interactions were generated using the car package (Fox & Weisberg, 2011).

### Preliminary Analyses: Stimulus Set Comparison

We first tested whether any effect of condition varied across the two Stimulus Sets in children and adults. For data from each age group, we generated a binomial generalized linear mixed effects model with Accuracy (0 or 1) as the outcome variable, Relation condition (Co-Occurrence, Taxonomic, and Unrelated) and Stimulus Set (1 vs. 2) as fixed effects, and participant and item as random effects. This analysis revealed no significant interaction between Relation condition and Stimulus Set (*p*s > .23). For all subsequent analyses, we therefore collapsed across Stimulus Sets.

### Primary Analyses

Accuracy by age and condition is presented in Figure 2. To test the relative influences of Relatedness conditions (Co-Occurrence, Taxonomic, and Unrelated) on accuracy, we generated an omnibus binomial generalized linear mixed effects model with Accuracy (0 or 1) as the outcome variable, Relatedness condition and Age group (children and adults) as fixed effects, and participant and item as random effects. This analysis yielded main effects of Relatedness condition ($\chi^2(2)=25.26$, $p<.001$) and Age group ($\chi^2(1)=10.36$, $p=.001$) that were qualified by an interaction ($\chi^2(2)=7.87$, $p=.02$).

To investigate the interaction between Relatedness condition and Age group, we conducted two sets of analyses: A first set in which we compared the effects of the different Relatedness conditions in each Age group, and a second set in which we compared the effects of each Relatedness condition in children versus adults.

**Relation Conditions in Each Age Group.** In these analyses, we generated for each age group a binomial generalized linear mixed effects model with Accuracy as the outcome variable, Relatedness condition as a fixed effect, and participant and item as random effects. These models

[1] We also analyzed participants’ errors to test the frequency with which the incorrect responses participants in each age group produced either co-occurred with or were taxonomically related to the Cue. However, these analyses did not contribute meaningfully to our results. The majority of incorrect responses in both age groups were other words from the set of word pairs the participant heard (64% in children, 82% in adults). Of these responses, only a small minority (7-14%) were either co-occurring with or taxonomically related to the Cue, which was likely the result of the random chance with which some words from the list, when randomly recombined with Cues, happen to be related to them in some way. Of responses not drawn from the list of word pairs, the only detectable pattern was a tendency for children to respond with incorrect words that co-occurred with the Cue (52%) more often than words that were taxonomically related to the Cue (6%). This pattern mirrors the results of analyses of children’s accuracy.

revealed significant effects of Relatedness condition in each age group (*p*s < .001) (Figure 3). To conduct pairwise comparisons of the Relatedness conditions in each age group, we re-generated the model for each age with each of the Relatedness conditions as the reference level, and applied Bonferroni-adjustments to the resulting p-values. In children, these analyses revealed significant differences between the Co-Occurrence (*M*=0.60, *SD*=0.49) and both Unrelated (*M*=0.25, *SD*=0.43) and Taxonomic conditions (*M*=0.29, *SD*=0.45) (*p*s < .001), but no difference between the Taxonomic and Unrelated conditions (*p* > .99). In adults, these analyses revealed a significant difference between the Co-Occurrence (*M*=0.71, *SD*=0.46) and Unrelated conditions (*M*=0.34, *SD*=0.48) (*p* < .0001), the Taxonomic (*M*=0.59, *SD*=0.49) and Unrelated conditions (*p*=.033), and no significant difference between Co-Occurrence and Taxonomic conditions (*p*=.237).

**Comparison of Children and Adults.** To compare the accuracy of children versus adults in each Relatedness condition, we generated a binomial generalized linear mixed effect model for each Relatedness condition, each with Age Group as a fixed effect, and participant and item as random effects. Additionally, we applied Bonferroni-adjustments to all p-values to correct for multiple comparisons. These analyses revealed only a significant difference between children and adults in accuracy in the Taxonomic condition (*p*<.001). In comparison, there was no significant difference in accuracy between children and adults in either the Co-Occur or Unrelated conditions (*p*s>.2).

## General Discussion

The purpose of the present experiment was twofold: (1) To investigate how semantic development is shaped by co-occurrence regularities and taxonomic relatedness, and (2) More broadly, to investigate whether the development of semantic organization involves the maintenance of early-emerging taxonomic organization throughout development (as in taxonomic bias accounts), the restructuring of semantic organization (as in restructuring accounts), or the addition of new semantic knowledge that does not replace earlier-emerging knowledge.

In this experiment, we observed substantial effects of co-occurrence in both young children and adults. In contrast, an influence of taxonomic relatedness was only apparent in adults. Importantly, due to our use of an implicit measure of semantic knowledge, this developmental pattern is unlikely to be attributable to developmental improvements in reasoning. These findings therefore support a key role for co-occurrence in semantic development, and are consistent with an overall developmental trajectory in which some types of semantic knowledge (such as taxonomic) tend to supplement rather than supplant earlier-emerging knowledge.

### Generalizability of Findings

In order to evaluate the support for a key role for co-occurrence in lexico-semantic development, it is important to consider the possibility that the cued recall paradigm used in this experiment biased the results in favor of this outcome. Specifically, accurately recalling pairs of words may better evoke participants' prior knowledge of word pairs that they have experienced occurring together than their knowledge of taxonomically related words.

However, this possibility is undermined by corroborating evidence from very different paradigms that do not involve recalling word pairs. First, as described in the introduction, findings from studies conducted by Fisher, Godwin, and Matlen (Fisher et al., 2011; Matlen et al., 2015) have provided evidence for the contribution of co-occurrence to semantic reasoning. Specifically, these studies found that young children only reliably infer that an item shares a property with another, strongly taxonomically related item when their labels co-occur (e.g., bunny-rabbit). Moreover, the pattern of results in adults and children has recently been replicated using another, very different paradigm in which the contribution of a given form of relatedness is measured based on the degree to which it interferes with participants' ability to identify when a picture (e.g., of a baby) does *not* depict the same thing as a preceding word (e.g., "bottle") (Unger & Sloutsky, Under Review). Taken together, these findings suggest a general contribution of co-occurrence to lexico-semantic knowledge that is not dependent upon the use of a cued recall-based assessment.

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